Subatmospheric Brayton-Cycle Engine Program Review

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SUMMARY

This program is to develop a solar-energy-powered electrical generator utilizing an engine developed for the Gas Research Institute (GRI). The generator consists of a subatmospheric, Brayton-cycle engine and a permanent-magnet (PM) alternator. The electrical power is generated by an alternator driven directly by the Brayton-cycle engine rotating group. Unique features that enhance reliability and performance include air foil bearings on both the Brayton-cycle engine rotating group and the PM alternator, an atmospheric-pressure solar receiver and gas-fired trim heater, and a high-temperature recuperator. The subatmospheric Brayton-cycle engine design is based on that of the GRI gas-fired heat pump engine.

Two generators will be supplied in the program: the first, a feasibility demonstration unit using existing GRI hardware, will produce an electrical power output of 5 kW; the second, an upgraded engine and PM alternator, will produce 8 kW.

INTRODUCTION

The increasing energy shortage has resulted in new developments in energy-saving devices. Utilization of the GRI gas-fired engine which provides onsite power for space conditioning allows full time operation of the solar energy electrical generator. The system offers high performance potential by utilizing air as the working fluid, where high turbine inlet temperatures provide high thermal efficiency. The engine measures 8 ft. by 4.5 ft. by 3 ft. Figure 1 shows the feasibility demonstration system consisting of the modified GRI subatmospheric Brayton cycle engine 5 kW PMA and Sanders solar receiver.

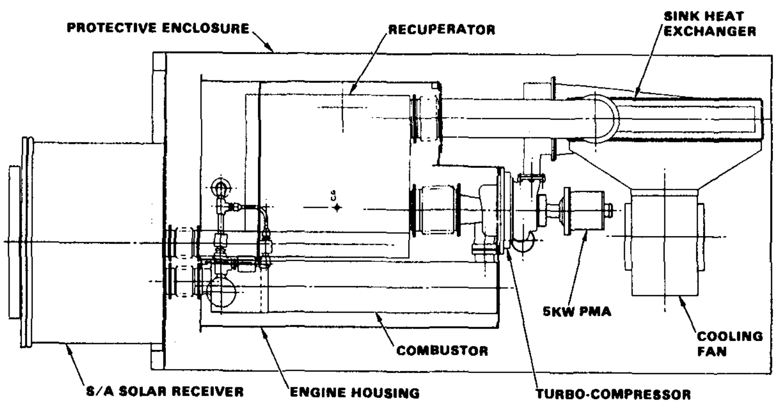

Figure 1. Feasibility Demonstration System

ENGINE DESCRIPTION

The Brayton cycle engine shown schematically in Figure 2 is a semi-open subatmospheric pressure cycle consisting of a centrifugal compressor, a radial inflow turbine, a recuperator, a sink heat exchanger, and an inline atmospheric combustor. Ambient air is drawn through the recuperator, where it is preheated before being introduced into the solar receiver. The heated air is then passed through the atmospheric-pressure, gas-fired combustor in a mixture that is slightly above stoichimetric. Compressor discharge gas is also cycled through the recuperator and is used as a diluent to provide added flow and the desired turbine inlet temperature. Expansion takes place through the turbine component, from which sufficient power is extracted to drive both the Brayton compressor and PM alternator. The turbine discharge gas, which is at subatmospheric pressure is processed through the recuperator, where is preheats combustor inlet air. The temperature of the low-pressure gas is reduced further by using the sink heat exchanger to reduce compressor power consumption. The compressor pumps the gas back to atmospheric and a small portion is exhausted; remainder is recycled as diluent.

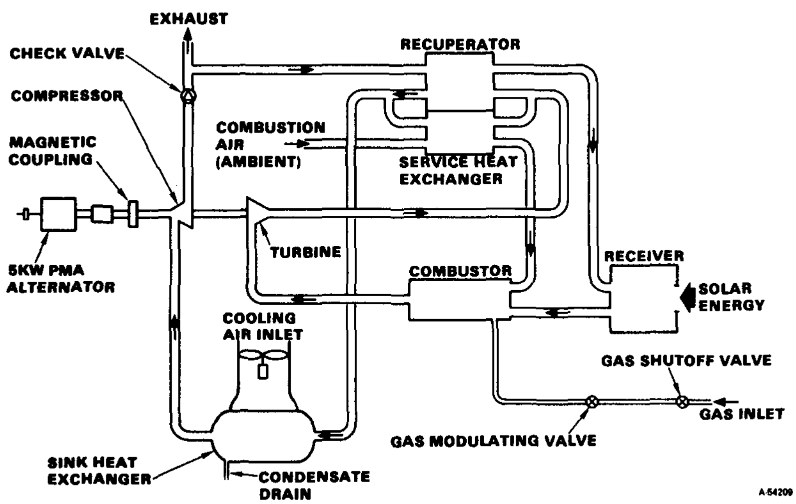

Figure 2. Simplified Schematic of the Feasibility Demonstration Unit

SYSTEM PERFORMANCE PREDICTIONS

Figure 3 presents the predicted engine performance characteristics for a 55°F ambient day cycle efficiency and output shaft power are plotted as functions of speed for varying turbine inlet temperatures. At the design point of 75,000 RPM and turbine inlet temperature of 1600°F the predicted cycle efficiency is 25%.

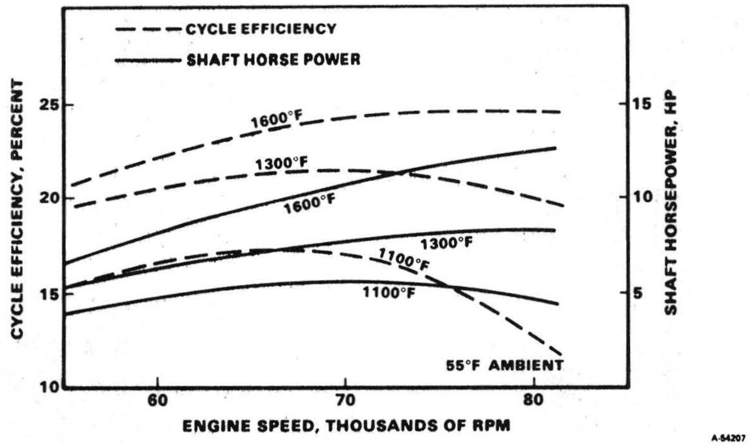

Figure 3. Brayton Engine Performance

HARDWARE DEVELOPMENT

5KW Feasibility Demonstration Unit

Existing GRI engine hardware components are used with required modifications to the engine housing and recuperator to accept the solar receiver and concentrator interface. A distribution duct was added to the cool side outlet of the recuperator to allow direct ducting to the solar receiver inlet shown in Figure 4.

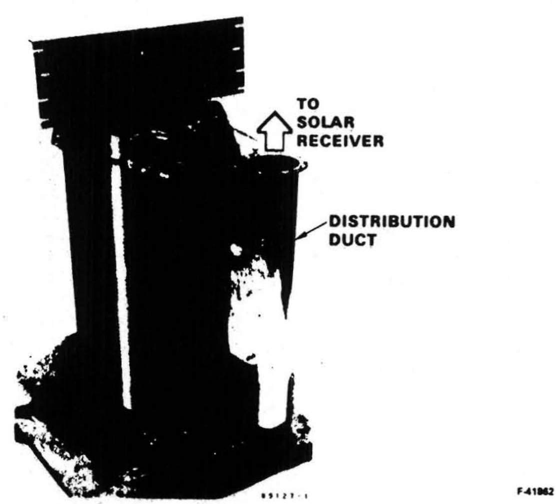

Figure 4. Modified GRI Recuperator

Modifications to the engine housing were required to incorporate the modified recuperator and a new design GRI combustor. Figure 5 shows these modifications with the new combustor installed. This combustor design incorporates an inlet port at the top.

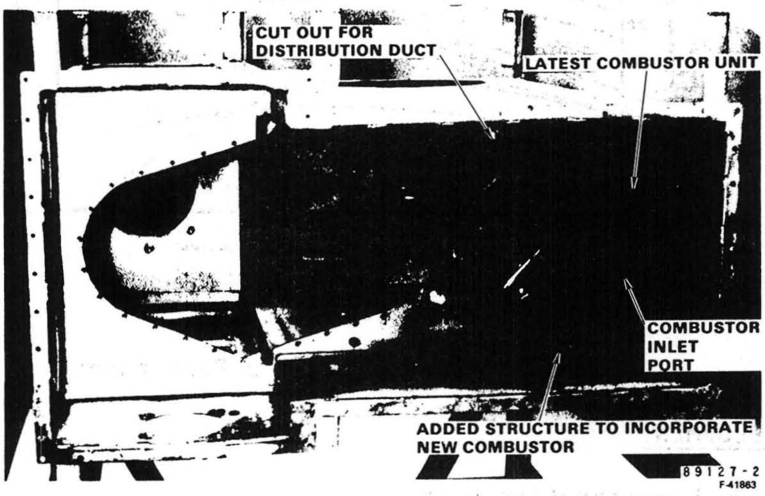

Figure 5. Engine Housing Modifications

This port is aligned directly with the solar receiver outlet port to minimize pressure drop and thermal loss. Additional modifications were required to the engine to realign the sink heat exchanger and provide a cooling air fan.

Hardware modifications are complete and final assembly is in process. Performance testing is scheduled for January and February 1984.

8KW Development Unit

Major redesign is with the PM alternator various approaches are being investigated, with compatibility with electric starting being of primary concern. One approach is to combine the PM alternator and turbocompressor on the same shaft eliminating the magnetic coupling and thrust/journal bearings in the PM alternator. A preliminary sketch of this design is shown in Figure 6.

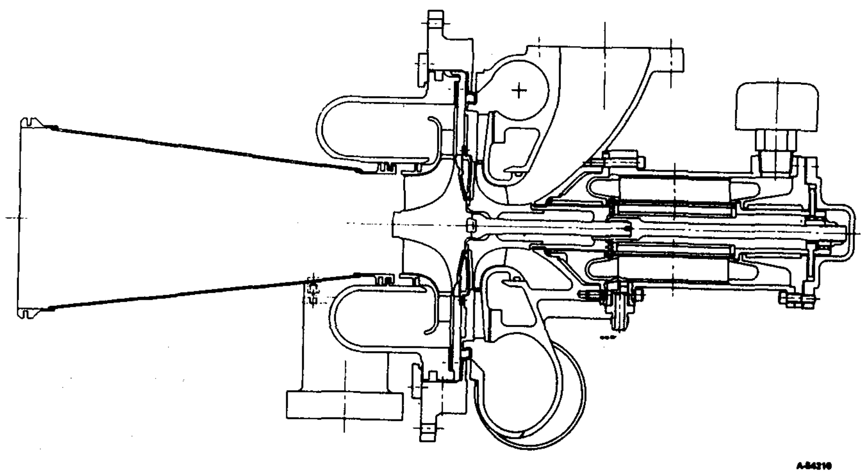

Figure 6. Preliminary Design of Turbogenerator

The alternate design approach is to have a stand alone PM alternator that is driven by a magnetic coupling. This design will require a larger PM rotor and stator plus the addition of a journal bearing and thrust bearing. The combined unit will share bearings with the turbocompressor.

The final design will be selected by mid December and detail design will proceed. System design is scheduled to be complete by March and system delivery in September 1984.